Vertebrate Physiology 437

1. Nervous System (CH6, CH7)

2. Short write-up due in lab tomorrow on Pelis et al. 2001

3. Term paper topic and annotated references due Thurs

4. Exam Thurs next week
Chapter 6 (con’t)

**Neuronal Communication**
- neurons
- support cells
- neuronal circuits
- synapses
Figure 8-13  Coding for stimulus intensity  Stimuli of different intensity change the frequency of action potential firing along the axon. Since all action potentials in a neuron are identical, the strength of the stimulus is indicated by the frequency of action potential firing. (a) A graded potential that is barely above threshold causes a series of action potentials to pass down the axon and release neurotransmitter. (b) A stronger graded potential increases the frequency of action potential firing in the axon and releases more neurotransmitter.
Figure 8.28  Presynaptic and postsynaptic inhibition  (a) In presynaptic inhibition, a modulatory neuron synapses on one collateral of the presynaptic neuron. In this way, one target of the neuron can be selectively inhibited. (b) In postsynaptic inhibition, all targets of the postsynaptic cell will be inhibited equally.
Presynaptic inhibition

Synaptic Efficacy

e.g., Cl\(^-\), K\(^+\) or alter Ca\(^{2+}\)

NT release via exocytosis: the role of Ca\(^{2+}\)
How can you have IPSP where $E_x$ greater (more +) than $V_{rest}$?
Presynaptic neuron can affect postsynaptic neuron as well as other neighboring neurons

**Neuromodulation:**
Changes in presynaptic efficacy that lasts from seconds to minutes

Longer term (more permanent) changes in presynaptic efficacy called **Synaptic Plasticity**
Synaptic Plasticity

- Important for learning and memory

- Presynaptic Efficacy often altered via Ca++ availability

1. Homosynaptic Modulation
   Modulation within the presynaptic neuron
   Typically short term

2. Heterosynaptic Modulation
   Modulation of presynaptic neuron by other neurons
   Often longer term (e.g., Behavioral sensitization)


Synaptic Plasticity

1. Homosynaptic Modulation

Synaptic facilitation:

More $\text{Ca}^{++}$ available

Synaptic depression:

NT vesicles unavailable
2. Heterosynaptic Facilitation (more short-term example)

(a) Sensory neuron

- Modulatory transmitter binds to receptor
- [cAMP] increases
- S-type K⁺ channels close
- AP is prolonged in synapse
- $I_{\text{Ca}}$ increases at terminal
- More transmitter is released

In sensory neuron

6-48 Randall et al. 2002
2. Heterosynaptic Facilitation

(more long-term example)

LTP

Long-Term Potentiation and

(Lt number of AMPA channels)

LTD

Long-Term Depression

Hippocampus plays important role in memory

NMDA and AMPA, both glutamate receptor agonists
Ch 7 Sensing the Environment

Sensory Reception
- Environment
- Within body

Integrated and Processed by NS

Sensory Receptors send signals to brain so perceive sensations

Sensory Receptor cells often organized into organs
Properties of Receptor Cells

Sensory Modality

Modalities include: vision, hearing, touch, taste, smell, chemical, thermal, proprioceptors

Qualities within each modality

  e.g., Red or yellow; High or low-pitched
Properties of Receptor Cells

**Receptor Cells**
- Specialized
- Selective for energy type and modality
- either is a neuron or
- Synapses immediately on a neuron

(1° afferent neuron to CNS)

Stimulus modifies conformation of receptor

7-2 Randall et al. 2002
Properties of Receptor Cells

Transduction:
Stimulus energy converted to nerve impulse

Example
Mechanosensors (touch)

1- Proteins respond to membrane distortion
2- Signal often amplified
3- Ion channels opened directly or indirectly
4- Current flows across membrane
5- Vm changes (aka receptor potential changes)
6- AP sent or NT released causing AP

7-2 Randall et al. 2002
Sensory Adaptation; Pacinian Corpuscle - Touch Example

Movement of Oil between layers is what triggers APs
Signal changes in pressure, not steady pressure

7-10 Randall et al. 2002
**Transduction**
- Stimulus reaches receptor cells
- Receptor protein is activated
- Cascade of protein interactions modifies intracellular second messengers
- Ion channels open (or close)
- Change in conductance produces a receptor current
- Receptor current changes $V_m$

**Amplification**
- Change in $V_m$ spreads electronically to spike-initiating zone
- Number and/or frequency of APs conducted along the axon changes
- Amount of transmitter released from receptor cell changes
- Number and/or frequency of APs conducted along axon of afferent neuron changes

**Graded events**

**All-or-none APs**
Mechanisms and Molecules

Lots of Evolutionarily Conserved Elements

e.g., 7 transmembrane helices and G-protein intermediate

e.g., Vision, olfaction, sweet and bitter taste (also muscarinic ACh receptors and many hormone receptors)

7-3 Randall et al. 2002
Mechanisms and Molecules

Enzymatic Cascade to amplify

Threshold of Detection
  e.g., 1 photon or hair cell
  movement of H diam.

Sour (pH; H+) and salt (Na+)
move directly – no amplification

To measure quality need many receptors grouped into organ; different ‘tunage’ (e.g, wavelength of light or frequency of sound)
Mechanisms and Molecules

Sensory Adaptation
(Recall Accommodation)
- orders of magnitude different stimulus strength
- often controlled via Ca++ availability
- local control or feedback from CNS

Type of stimulus received depends on where in CNS (~brain) AP arrives.

Rub eyes and see light!

Intensity signalled by frequency of APs, but...
Stimulus Intensity and **Dynamic Range**

From lowest **threshold**, to upper limit imposed by refractory period:

(a) Amplitude of receptor potential (arbitrary units)

- Limited by reversal potential

(b) Frequency of APs (impulses · sec\(^{-1}\))

- Limited by refractory period

(c) Combining (a) and (b)

- Frequency varies linearly with the size of the receptor potential, but cannot exceed the limit set by the refractory period.

Note log axis

7-7 Randall et al. 2002
Dynamic Range

Shifting range of appropriate AP frequency

Detectable light intensity varies over 9 orders magnitude

Detectable sound intensity varies over 12 orders magnitude

Range Fractionation

- Function of sensory adaptation
- Also recruit receptors with different ‘tunage’ or sensitivity (e.g., rods and cones in eye)
Sensory Adaptation Possibilities in more detail (see p.226)

1. Receptor cell mechanical properties may filter

2. Receptor cells may be depleted (e.g., visual pigments; need to be regenerated)

3. Enzyme cascade (during amplification) may be inhibited by (intermediate) product

4. Electrical properties change b/c $\uparrow [\text{Ca}^{++}]$

5. Accommodation of spike initiating zone

6. Sensory adaptation in downstream neurons (CNS)
Enhancing Sensitivity

- Spontaneous basal activity
- Constant rate of APs
- Directionality if ↑ or ↓ AP frequency

(b)

7-12 Randall et al. 2002
Enhancing Sensitivity

- **Efferent Control**
  
  e.g., stretch receptors in muscle control length so can perceive stretch

- **Feedback Inhibition**
  
  Auto (helps keep in dynamic range) vs. Lateral...
Enhancing Receptor Sensitivity

- Lateral Inhibition

  e.g., improve touch sensitivity and visual acuity (edges especially)
End